

INSULATED GATE BIPOLAR TRANSISTOR WITH REVERSE CONDUCTING CURRENT

TECHNICAL FIELD

This is a continuation of application Ser. No. 07/678,312, filed as PCT/JP90/01091, Aug. 29, 1990, which was abandoned upon the filing hereof.

This invention relates to an insulated gate bipolar transistor having a reverse conducting function built therein.

BACKGROUND ART

Recently, attention has been paid to insulated gate bipolar transistors (referred to as IGBT) as shown in FIG. 14 that are usable as power elements for which high withstand voltage and low on-resistance are required.

Since this type of transistor has a p^+ layer on the side of a drain D, a low on-resistance is attained; but, its turn-off time is long as compared with a usual power MOSFET.

Generally, power switching elements of this type are used as switches of power converting units such as inverters, to which reverse conducting diodes are connected in parallel. As pointed out in Japanese Patent Laid-Open No. 61-15370, the usual power MOSFET has the reverse conducting diode built therein; but, the IGBT has no built-in diode, thus must have such a reverse conducting diode connected externally.

In view of the foregoing problems, Japanese Patent Laid-Open No. 61-15370, for example, has proposed a configuration as shown in FIG. 15. In this drawing, a portion of a p^+ layer 11 on the side of the drain (corresponding to a reverse conducting diode region 5 as shown) is replaced with an n^+ layer 11N of the opposite conduction type so that a reverse conducting diode is built in integrally. Further, an n^+ layer 25 is formed for restricting the injection of positive holes from the p^+ layer 11 on the side of the drain without affecting the on-resistance appreciably, whereby the lifetime of carriers in an n^- drain layer 12 is decreased, thereby shortening the turn-off time.

In fact, by virtue of the n^+ layer 25 disposed between the p^+ layer 11 and the n^- drain layer 12, the efficiency of injection of positive holes from the p^+ layer 11 into the n^- drain layer 12 is decreased. However, since the whole current flowing through an n^+ source layer 14 and the p^+ layer 11 is given by the sum of electrons and positive holes, the foregoing decrease in the efficiency of injection of positive holes results in a decrease in the current of positive holes which forms part of the whole current, that is, the amount of minority carrier (positive hole) accumulated in the n^- drain layer 12 decreases, and the amount of positive hole contributing to conductivity modulation in the n^- drain layer 12 also decreases; as a result, the on-resistance increases inevitably.

Another configuration is shown in FIG. 16 has also been proposed (see "Extended Abstract of the 18th Conference on Solid State Devices and Materials", Tokyo, 1986, pp. 97-100) which is characterized in that an n^+ region 26 is formed in a marginal surface portion of an IGBT element, and this n^+ region 26 is electrically connected to a drain electrode 22, whereby the injection of minority carrier (positive hole) into the n^- layer 12 is restricted, thereby shortening the turn-off time of the IGBT.

In this second configuration, a reverse conducting diode is virtually or parasitically built in wherein a reverse conducting current flows through the path defined by a source electrode 18, p layer 13, n^- layer 12, n^+ layer 26, external

wire 34', and drain electrode 22 in that order. However, the lateral resistance of the n^- layer 12 is high especially when the IGBT is designed to exhibit a high withstand voltage. Accordingly, even if it were tried to attain the reverse conducting function by the use of the foregoing path, the resultant operating resistance is high thus, the reverse conducting diode seeming to be built in cannot function practically as required.

The present invention has been devised in view of the foregoing various problems, thus its object is to provide an insulated gate bipolar transistor (IGBT) having a reverse conducting function of low operating resistance built therein, whose turn-off time is short and whose on-resistance is low.

DISCLOSURE OF THE INVENTION

To accomplish the foregoing object, in an insulated gate bipolar transistor according to the present invention, a first semiconductor layer of a first conduction type is formed on the side of a drain, a second semiconductor layer of a second conduction type for causing conductivity modulation upon carrier injection is formed on the first semiconductor layer, a third semiconductor layer of the first conduction type is selectively formed on the surface of the second semiconductor layer, a fourth semiconductor layer of the second conduction type is selectively formed on the surface of the third semiconductor layer, a gate electrode is formed on the surface of the third semiconductor layer between the second semiconductor layer and the fourth semiconductor layer with a gate insulating film interposed between them, a source electrode is formed as to spread from the surface of the third semiconductor layer to the surface of the fourth semiconductor layer, and a drain electrode for supply of a drain current is formed on the side of the drain.

In the foregoing configuration, a fifth semiconductor layer of the second conduction type for passing therethrough a reverse conducting current opposite in direction to the drain current is formed in a given region within the second semiconductor layer which is electrically connected to the drain electrode, and a sixth semiconductor layer of the second conduction type is formed at or in the vicinity of the interface between the first semiconductor layer and the second semiconductor layer with an impurity concentration higher than that of the second semiconductor layer into a given pattern such that a region for passage of carriers is left to decrease the electric resistance between the fifth semiconductor layer and a region of the second semiconductor layer that is spaced apart from the fifth semiconductor layer and to allow the carriers to be given and received between the first semiconductor layer and the second semiconductor layer, whereby a reverse conducting function is provided.

Specifically, by providing the fifth semiconductor layer and electrically connecting the fifth semiconductor layer to the drain electrode using a conductor, there are formed a pn junction diode composed of the second and third semiconductor layers and a transistor (referred to as a reverse transistor) whose emitter, base and collector correspond to the third, second and first semiconductor layers, respectively, whereby the reverse conducting function is provided. Further, by forming the sixth semiconductor layer of the same conduction type as of the second semiconductor layer with an impurity concentration higher than that of the second semiconductor layer, the operating resistance of the reverse conducting function is decreased by virtue of the sixth semiconductor layer. That is, the sixth semiconductor